GROWTH AND MORTALITY OF LITTLE TUNNY (*EUTHYNNUS ALLETTERATUS*) LARVAE OFF THE MISSISSIPPI RIVER PLUME AND PANAMA CITY, FLORIDA

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ABSTRACT

Larval and early juvenile little tunny, *Euthynnus alletteratus*, were collected from the northern Gulf of Mexico (434 fish from the Mississippi River delta region and 150 off Panama City, Florida) using a 1 × 2 m, 0.947-mm mesh neuston net and a 1 × 1 m, 0.333-mm mesh Tucker trawl. Sagittae were removed from 200 fish collected from the Mississippi River delta region and 150 collected from off Panama City, Florida, and examined whole at 800X magnification. Daily growth increments were visible in the sagittae of little tunny (2.5–14.0 mm SL) which ranged in age from 2 to 13 d. Growth estimated as the slope of a regression of SL on age, was rapid (1.07 mm d^{-1}). Fish collected off Panama City grew faster than those collected in the vicinity of the Mississippi River discharge plume. Instantaneous daily mortality rates, estimated from survivorship curves were higher in the Mississippi River plume fish (0.95) than those from Panama City, Florida (0.72).

Previous studies have shown that phytoplankton, zooplankton and fish larvae are concentrated in the vicinity of the Mississippi River discharge plume in general, and its frontal region in particular (Govoni et al., 1989; Grimes and Finucane, 1991; Dagg and Whitledge, 1991). These concentrations, due at least partly to physical aggregation (Govoni and Grimes, 1992), create a potentially rich feeding environment for fish larvae. Grimes and Finucane (1991), therefore, hypothesized that larvae associated with the plume would consume a superior diet, grow faster and thus experience a shorter larval stage duration and have a higher survival rate than elsewhere. Larvae and early juveniles of several fish species have been shown to exhibit faster growth off the Mississippi River discharge plume than in other areas of the Gulf of Mexico and Atlantic Ocean (DeVries et al., 1990; Leffler and Shaw, 1992). Growth also varies along salinity gradients associated with the plume (Lang et al., 1993; Day 1993; Grimes and DeVries, unpubl. data). However, because the factors that concentrate larval fish prey in the vicinity of the plume probably also concentrate predators, fish larvae may experience higher mortality rates in the plume than elsewhere (Day, 1993; Grimes and DeVries, unpubl. data).

Little tunny, *Euthynnus alletteratus,* are common scombrids in tropical and subtropical waters of the Atlantic Ocean, Mediterranean Sea, Black Sea, Caribbean Sea and the Gulf of Mexico (Collette and Nauen, 1983). The species has little commercial value in the United States, however, it is a popular game fish and is sometimes sold commercially outside the U.S. (Mather and Day, 1954).

Although larvae and early juveniles of many scombrids have been aged, including, bluefin tuna, *Thunnus thynnus* (Brothers et al., 1983), yellowfin tuna, *Thunnus albacares* (Lang et al., 1993), king mackerel *Scomberomorus cavalla* and Spanish mackerel *Scomberomorus maculatus* (DeVries et al., 1990), black skipjack, *Euthynnus lineatus* (Wexler, 1993), skipjack, *Katsuwonus pelamis* (Radkte, 1983), and Atlantic mackerel, *Scomber scombrus* (Kendall and Gordon, 1981), no results have been published on age and growth of wild larvae or early juvenile little tunny.

The objective of this study was to provide additional evidence for evaluating the original hypothesis set forth by Grimes and Finucane (1991) that larvae as-

sociated with the Mississippi River plume, and its frontal region in particular, have higher growth and survival rates than those found elsewhere, presumably as a result of better feeding conditions. Herein we estimate age and growth of little tunny larvae and early juveniles, and compare growth and mortality rates between the Mississippi River plume region and off Panama City, Florida.

MATERIALS AND METHODS

Little tunny were collected from two locations in the northern Gulf of Mexico, off the Mississippi River delta and 2.0–4.0 km off Panama City, Florida. Temperature (°C), salinity (‰) and depth (m) data were collected at each station with an STD (salinity, temperature and depth device). Little tunny were collected during both day and night off the Mississippi River delta on four cruises: 2–9 September 1987, 27–31 May 1988, 25 August to 1 September 1988 and 1–10 September 1989. Samples were collected with a 1x2 m, 0.947-mm mesh neuston net towed at the surface at 2 kn for 10 min and a 1 × 1 m, 0.333-mm mesh Tucker trawl fished obliquely from mid-depth to the surface at 1.2–1.5 kn for approximately 3 min. All little tunny larvae collected from off Panama City, Florida were captured between 21:00 and 23:00 on 12 July 1988 using the neuston net. Following capture all fish were preserved in 95% ethanol for 24 h, after which the ethanol was drained and fresh ethanol added. In the laboratory all fish were measured to the nearest 0.1-mm standard length (SL) using a dissecting microscope (50× magnification) and an ocular micrometer. Larvae were identified mainly by the pigmentation on the forebrain, lower jaw ramus and first dorsal fin (Richards, 1989). The largest otolith, the sagittae, was removed with fine probes under plane polarized light. Otoliths were washed with distilled water, dried, and mounted using the polymer mounting medium Flo-Texx [Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.] Polishing of the otoliths was not required for increment analysis.

Mounted sagittae were examined whole at 800X magnification under polarized, transmitted light using a compound microscope to make increment counts. Increments were counted by the same reader twice, with several days between repeat counts, and without knowledge of prior counts. Fish with identical counts were included in the analysis, while those that differed were counted a third time. If there was no agreement on the third count the otolith was rejected.

To determine the relationship between SL and otolith radius, we measured radii on sagittae of larvae from the Mississippi River delta region using an image analysis system. The radius was measured (μm) opposite the rostral region. The regression of SL on otolith radius was used to back-calculate lengths at age to compare to observed lengths at age. We estimated growth by least squares linear regression of length on age, using linear, logarithmic and exponential models and present the model with the highest coefficient of determination (r^2). We used multiple regression to evaluate the effects of temperature on growth then performed an analysis of variance (ANOVA) on the residuals to control for temperature effects while testing growth differences among areas.

A catch or survivorship curve approach was used to estimate instantaneous daily mortality rates. We plotted the age-frequency distribution, then regressed the $\log_e$ frequency on age of the descending limb of the plot. We included the most frequently occurring age in the regression, reasoning that to do otherwise would bias slopes downward. Slopes of the regressions are estimates of daily instantaneous mortality rates (Ricker, 1975).

Neuston catches were used to estimate and compare mortality rates between the two sites because the neuston net was the less size selective of the two gear types and no Tucker trawl collections were made off of Panama City. Because all of the fish collected from Panama City were caught at night, only night catches were used from the Mississippi River plume for calculating and comparing mortality rates. We did not age all fish from each sample location, unaged fish were aged using a sample site specific growth curve.

RESULTS

We collected 434 fish from off the Mississippi River delta (2.5–14.0 mm SL) and 150 fish from off of Panama City, Florida (3.5–13.0 mm SL), (Fig. 1). Two-hundred sagittae were removed from Mississippi River delta fish and 150 from Panama City fish, and we were able to assign ages to 106 (2.5–14.0 mm SL) and 110 (3.5–13.0 mm SL) of these fish, respectively. Presumed ages ranged from 2 d for a fish 2.5 mm SL to 13 d for a 14 mm SL fish. Growth increments, as defined by Brothers et al. (1983), were visible on the sagittae of little tunny (Fig.
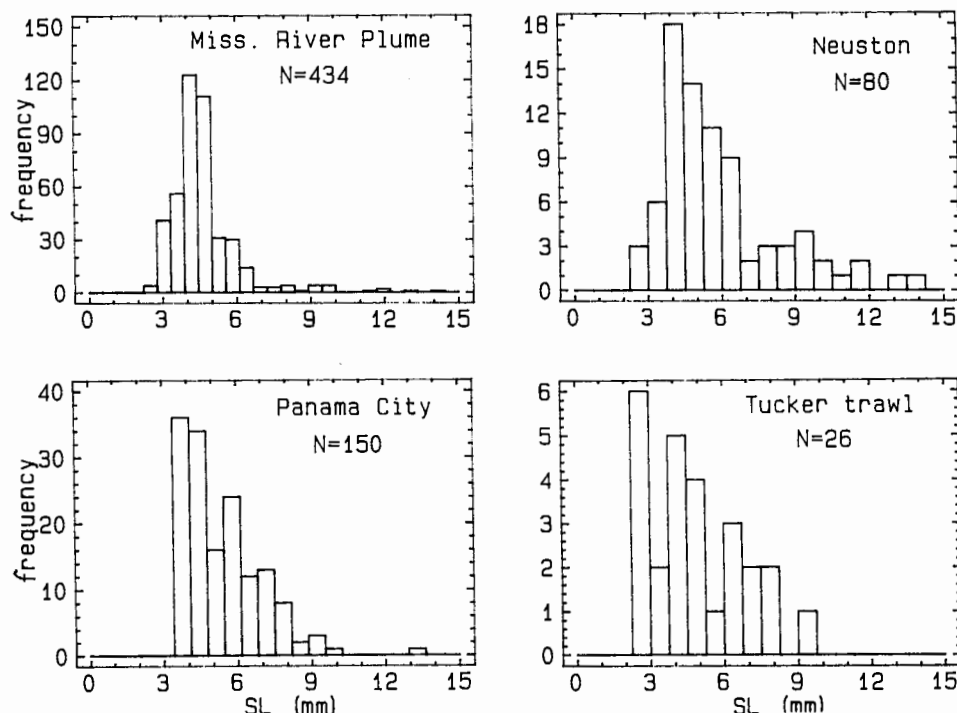
Figure 1. Length-frequency distribution of little tunny (*Euthynnus alletteratus*) collected off the Mississippi River discharge plume (1987–89) and Panama City, Florida (1988) and method of collection (neuston net and Tucker trawl) from the Mississippi River Plume.

2). The otoliths appeared circular to oval in shape with a darkened primordial region; the rings were more pronounced and visible distal to the primordium.

We did not directly establish that growth increments were deposited on a daily basis. However, several lines of evidence suggest that this is the case. Otolith radius and standard length were proportional ($r^2 = 0.79$, $P < 0.001$) (Fig. 3). Using the regression of SL on otolith radius we back-calculated lengths at the fourth increment to compare to observed length at the fourth increment and the lengths agree reasonably well (Fig. 4). Observed size of 4-d old fish ranged from 3.4–6.7 mm SL and averaged 4.7 mm SL ($n = 31$), while the same statistics for back-calculated size at age 4 d were 4.9–5.9 mm and 5.3 mm SL ($n = 23$). Additionally, the variance in SL at age 4 d is higher for observed than for back-calculated data, 0.74 as compared to 0.09.

Little tunny grow rapidly, on average greater than 1 mm d^{-1}. The slope of the least squares linear regression of SL on age for little tunny (SL = 1.08 + 1.07 age, $n = 216$, $r^2 = 76.2$) is an estimate of the overall growth rate in mm/d for both sampling locations combined (Fig. 5). Fish were collected May, July, August and September when sea surface temperatures ranged from 24.7–32.2°C. Mean individual growth (SL/age) for both sites combined was approximately 1.2 mm d^{-1} at the lowest and highest observed temperatures (approximately 24° and 32°C respectively) and 1.5 mm d^{-1} at 28°C. However, when we tested for a quadratic relationship between temperature and growth using multiple regression, a significant effect was not detected (Table 1).

When we controlled for the effect of sea surface temperature on growth, little

Figure 2. Whole sagittal otolith from a 7 d old, 9.3 mm standard length (SL) little tunny (*Euthynnus alletteratus*) (800×).

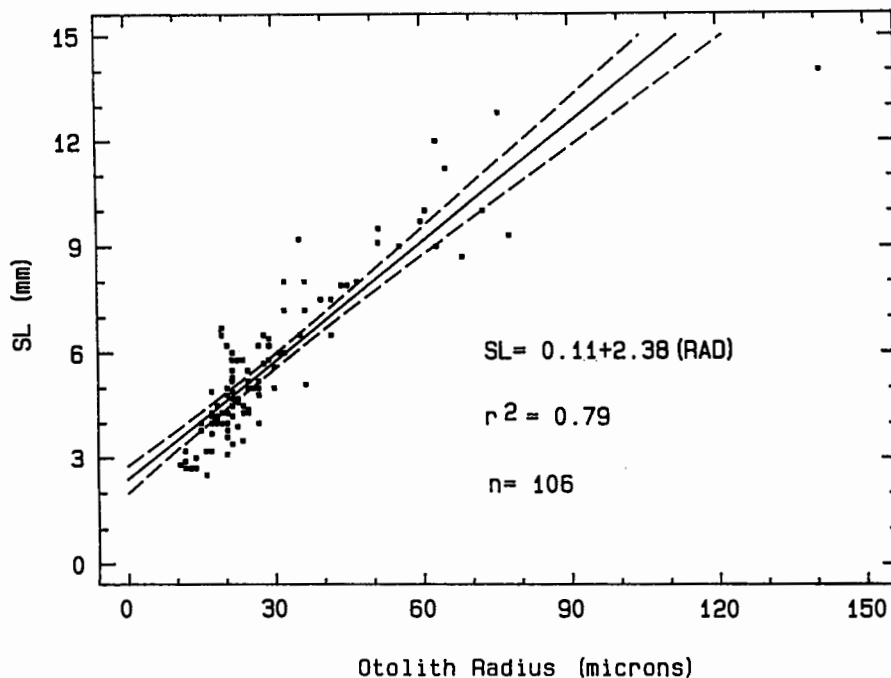$$SL = 0.11 + 2.38 \, (RAD)$$

$$r^2 = 0.79$$

$$n = 106$$

Figure 3. Linear regression of standard length (SL) on otolith radius; dotted lines represent 95% confidence limits.
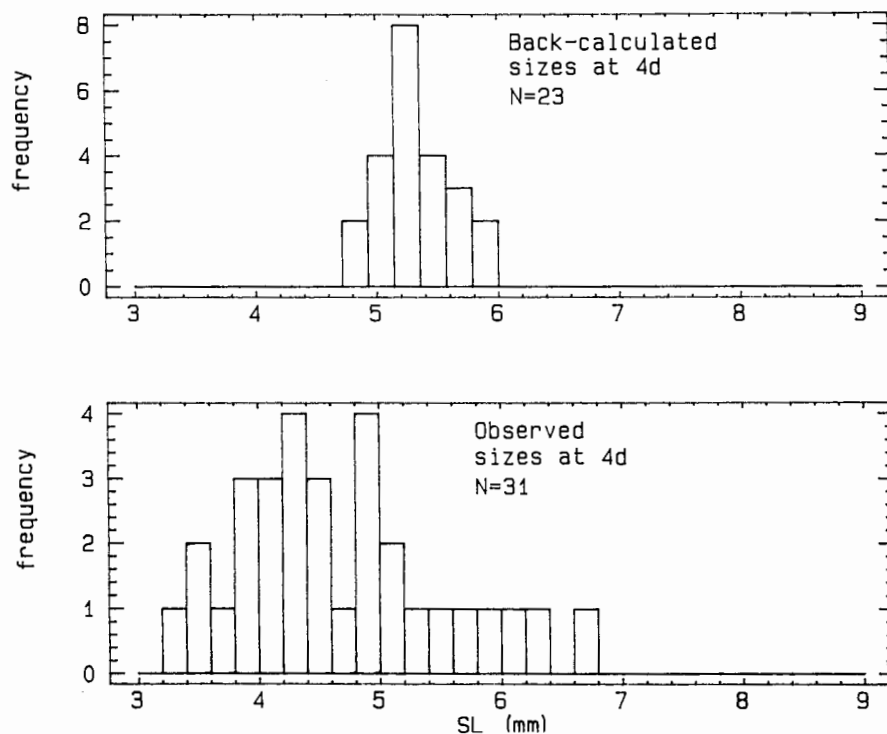
Figure 4. Frequency distribution of observed and back-calculated standard lengths (SL) at age 4 d.

tunny collected off Panama City grew 25% faster than those collected in the Mississippi River plume (Panama City = 1.51 mm d^{-1}, SE = 0.035, n = 110; Mississippi plume = 1.21 mm d^{-1}, SE = 0.036, n = 104) (Table 2). When growth differences between the two collection sites were examined collection site was found to be a highly significant effect in the model (Table 2).

Although both the neuston net and Tucker trawl catches exhibited evidence of size-selectivity, we judged the neuston catches most representative to use for estimation of mortality rates. The neuston net caught more large fish than the Tucker trawl, but fish were fully vulnerable to the Tucker trawl at a smaller size, i.e., 3.0 mm SL as compared to 4.0 mm SL for the neuston net (Fig. 1). Because we did not age all fish from each sample location, we used a sample site specific growth curve to estimate the age of 172 of 278 fish used to construct the catch curve for the Mississippi River plume and to estimate age for 40 of the 150 fish used for Panama City catch curve (Fig. 6). The daily instantaneous rate of mortality (z) was 0.72 and 0.95 using ages 6–10 d for Panama City and 4–13 d for Mississippi plume, respectively.

DISCUSSION

Growth increments observed in little tunny were similar in appearance to those found in other scombrids such as bluefin tuna (Brothers et al., 1983), yellowfin tuna (Lang et al., 1994), and king and Spanish mackerel (DeVries et. al., 1990).·

We did not directly establish that growth increments were deposited on a daily basis. However, similar to DeVries et al. (1990) for the confamilial king mackerel and Spanish mackerel, we showed that fish growth and otolith growth are strongly
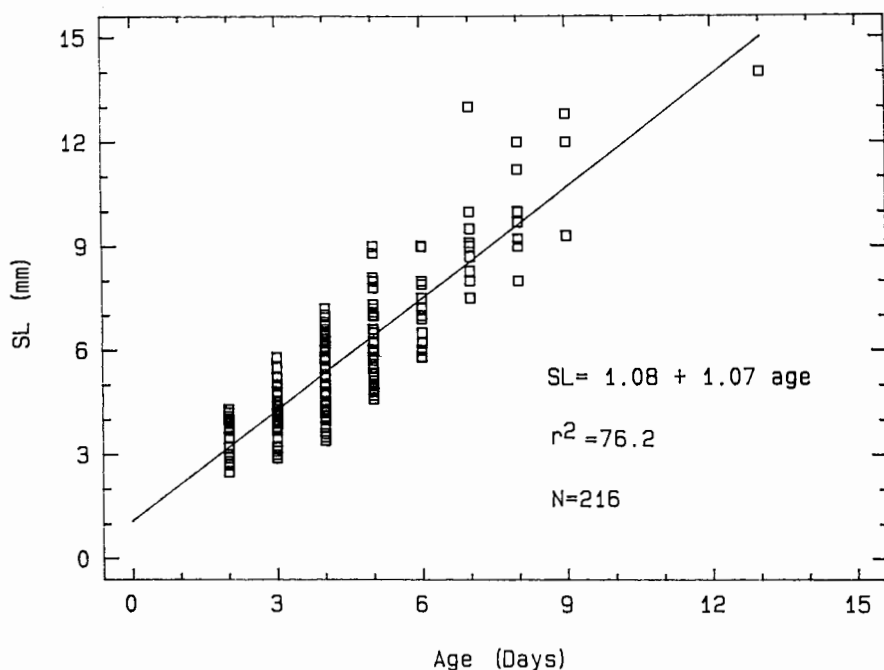
Figure 5.   Relationship between SL (mm) and age (d) of little tunny (*Euthynnus alletteratus*) from the Mississippi River plume and Panama City, Florida.

related, and that back-calculated and observed lengths at ring four agree somewhat, although back-calculated sizes tend to be larger than observed. In addition, daily deposition of growth increments has been directly validated in two other species of scombrids—skipjack tuna using known age fish (Radtke, 1983), and black skipjack using a tetracycline hydrochloride marker (Wexler, 1993). Furthermore, Houde and Richards (1969) and Mayo (1973) collected little tunny eggs in the wild and reared larvae in the laboratory, and found that the lengths of these fish at 2 d post-hatch were 3.1–4.2 mm, respectively. These sizes at known age agree well with our observed lengths at presumed ages 2 d (2.7 and 4.5 mm).

The back-calculated sizes at age 4 d tended to be larger than observed sizes at the same age and the variance is also higher for the observed data. Size selective mortality may have removed the slow growing larvae from the back-calculated sample and thus biased the size-frequency distribution toward faster growing fish, as compared to the observed length at age 4 d sample (Fig. 4). This culling of slower growing larvae may have also reduced the variance in length at age 4 d in the back-calculated relative to observed data. Similarly, Post and Prankevicius

Table 1.   Multiple regression of SL on temperature, temperature squared and age to test for a quadratic relation between temperature and growth.

Independent variable	Coefficient	SE	t-value	Sig. level
Constant	3.89	21.71	0.18	0.86
Temperature	0.07	1.53	0.05	0.96
Temperature squared	<0.006	0.03	−0.24	0.81
Age	1.13	0.04	28.98	0.0000

Table 2. Analysis of variance of the residuals of the regression of SL on temperature, temperature squared and age to test differences in growth between sample location (off Panama City and in the Mississippi River plume) while controlling for the effect of sea surface temperature.

Source of variation	Sum of squares	df	Mean square	F-ratio	Sig. level
Between locations	3.94519	1	3.9451906	4.817	0.0293
Within locations	173.61471	212	0.8189373		
Total (corrected)	177.55990	213			

(1987) compared daily observed and back-calculated lengths of yellow perch, *Perca flavescens,* for specific dates and found that observed lengths at age were less than back-calculated, a result attributed to size-selective mortality. Pepin (1988) used a stochastic numerical model to simulate the influence of variation in food and abundance of size-selective predators on growth and survival of fish larvae. He concluded that for any given prey level, as predation pressure increased the culling of slow growing larvae by predators results in an apparent increase in growth, and also reduces the variance in growth. Grimes and Isely (in revision) examined back-calculated lengths at age in king mackerel, *Scomberomorus cavalla,* and Atlantic menhaden, *Brevoortia tyrannus,* and found a trend toward larger back-calculated size at age in older larvae, as well as higher average variation in length at age in observed as compared to back-calculated data; they attributed both trends to size-selective mortality.

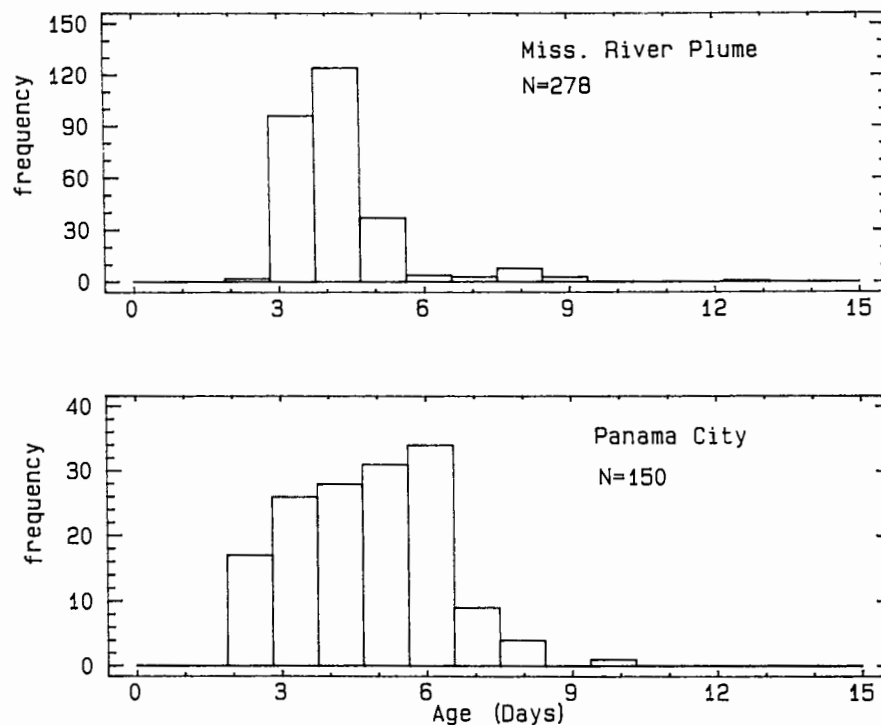Little tunny, like their confamials, exhibit extremely rapid growth. Their growth

Figure 6. Age frequency distribution of little tunny (*Euthynnus alletteratus*) used to estimate daily instantaneous mortality rates.

rate of 1.07 mm d^{-1} is similar to that of king and Spanish mackerel (0.82 and 1.31 mm d^{-1}, respectively; DeVries et al., 1990), yellowfin tuna (0.89 mm d^{-1}; Lang et al., 1993) and black skipjack (0.70 mm d^{-1}; Wexler, 1993). Although Lang et al.(1994) showed a parabolic relation between sea surface temperature and growth for yellowfin tuna, *Thynnus albacares,* with the optimum temperature for growth at 29.0–29.5°C, we could not demonstrate a significant quadratic relationship between temperature and growth in little tunny. In addition, we found that growth of fish associated with the Mississippi River plume was significantly less than for fish from off Panama City. This is inconsistent with the findings of DeVries et al. (1990) for king mackerel and Leffler and Shaw (1992) for Atlantic bumper, and does not support the hypothesis that fish larvae associated with the Mississippi River plume experience superior growth conditions.

The instantaneous mortality rates we determined for little tunny (0.95 and 0.72 for the Mississippi River plume and Panama City, respectively) are higher than have been reported for other scombrids such as yellowfin tuna (0.33; Lang et al., 1994), king mackerel and Spanish mackerel (0.82 and 0.68; Grimes and DeVries, unpubl. data) and Atlantic mackerel (0.35; Kendall and Gordon, 1981). It is our view that the mortality rates we report seem unusually high and are only rough approximations. Several necessary assumptions of a catch-curve analysis were probably violated to some degree. For example, recruitment of larvae is probably pulsed, not constant, due to both spawning behavior of adults and the patchy spatial distribution of larvae. Equal vulnerability to capture at size and age after full vulnerability to the sampling gear is an assumption that is almost certainly violated for older/larger larvae, because older/larger individuals are able to avoid the net. Decreasing vulnerability to capture with age may explain why rates are unusually high because older/larger larvae may not be represented in proportion to their true abundance, thus increasing the slope of the catch curves. These issues are cause to question the absolute value of the reported mortality rates. However, because we computed rates using only fish from neuston collections, we believe the estimates are useful for comparisons among regions and tend to indicate, as have other studies (Grimes and DeVries, unpubl. data; Day, 1993) that mortality rates for fish larvae may be higher in the vicinity of the Mississippi River discharge plume, probably because the factors which concentrate larval prey also concentrate their predators.

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